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Study of Interference in WiFi-WiMAX Network

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Abstract*—Wireless mesh networks are evolving at a rapid rate. They overcome most geographical, temporal and organizational barriers to the transfer of data. Interference in wireless systems is one of the most significant factors that limit the network capacity and scalability of wireless mesh networks. Interference in IEEE 802.11 may be the result of the electronic devices or other Wi-Fi base stations that work in the same bandwidth. Interference in WiMAX/802.16 mesh is a major issues nowadays of several phenomena, namely concurrent transmissions in the neighborhood and data collisions (that need to be avoided) at a receiver from transmitting nodes that are outside the range of each other (hidden terminal nodes). So, there is need to perform vital algorithm to overcome from the difficulties of the same. In this paper, we study the problem of Minimizing Interference (MI) in Wi-Fi-WiMAX hexagonal mesh scheduling networks by appropriately routing end connections and assigning slots to them. The proposed model includes the effect of hidden terminal nodes as well as the interferences coming from neighboring nodes. The proposed results on the basis of delay yields better network performance, a consequence of the improved network spatial reuse.
***Keywords*— Wireless Network, WiMAX Network, Interference, Mesh Network**

I. INTRODUCTION

Wireless networks are networks which provide users with connectivity regardless of their actual physical location [1]. They have characteristics that are unique to them, such as the ability to withstand unfavourable environmental conditions, path planning , communication failures, large scale of deployment, scalable node capacity, node mobility, unattended operation as well as limited power, to name a few. Multi-hop wireless networks have been a subject of much study over the past few decades. Much of the original work was motivated by military applications such as battle-field communications. More recently, however, some interesting commercial applications have emerged, such as "community wireless networks" and "sensor networks".[11] A fundamental issue in multi-hop wireless networks is that performance degrades sharply as the number of hops traversed increases. Interference: As all the wireless devices use air for transmitting the data, transmissions by any device at the same frequency as an access point's radio can cause interference. Interference can make wireless connections weaker and unreliable. In addition, wireless access points sharing the same channel might interfere with each other. Interference creates collisions, prevents reception, and wastes scarce bandwidth. Wireless networks strive to prevent senders from interfering. They may reserve the medium to a specific node using TDMA or probe for idleness as in 802.11. This fear of interference is inherited from single-channel design and may not be the best approach for a wireless network. With bandwidth being scarce in a wireless network, enabling concurrent receptions despite interference is essential [10].

A. Wi-Fi

Wi-Fi is the popular name for the wireless Ethernet 802.11b standard for WLANs. Wireless local area networks (LANs) emerged in the early 1980s as a way to allow collections of PCs, terminals, and other distributed computing devices to share resources and peripherals such as printers, access servers, or shared storage devices. One of the most popular wired LAN technologies was Ethernet. Over the years, the IEEE has approved a succession of Ethernet standards to support higher capacity LANs over a diverse array of media. The current generation of WLANs support up to 11 Mbps data rates within 100m of the base station [2]. Moreover, in simple words Wi-Fi is a brand name for short-distance wireless communication networking technology, based on 802.11 standards that Wi-Fi Alliance has adopted from IEEE, while wireless stands for computer network that is not connected by cables and utilizes cellular towers for data transmission.

Interference: Wi-Fi interference is a common and troublesome problem. Interference hampers coverage and capacity, and limits the effectiveness of both new and existing systems. As 802.11 wireless networks operate in unlicensed bands used by many technologies, such as microwave ovens, bluetooth devices, video surveillance cameras, cordless phones and wireless speakers (that operate in the 2.4 GHz or 5 GHz bandwidth) they are subject to interference. Various effects of interference: a decrease in the wireless range between devices, a decrease in data throughput over Wi-Fi, intermittent or complete loss of the wireless connection and when Voice over IP (VoIP) calls are placed. VoIP requires significant bandwidth because resending voice is not an option—the result is dropped or jittery voice transmission. [9].

B. WiMAX

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The term WiMAX, is an acronym for Worldwide Interoperability for Microwave Access, is commonly used to refer to a collection of standards, products, and service offerings derived from the IEEE 802.16 family of standards. The IEEE standards include many implementation options that are left to the discretion of equipment vendors or network operators. Conflicting design choices can make interoperation of the equipment of multiple vendors problematic. The WiMAX forum was organized by equipment vendors in 2001 to define operational profiles, certify interoperability, and promote the use of the technology [3], [4].

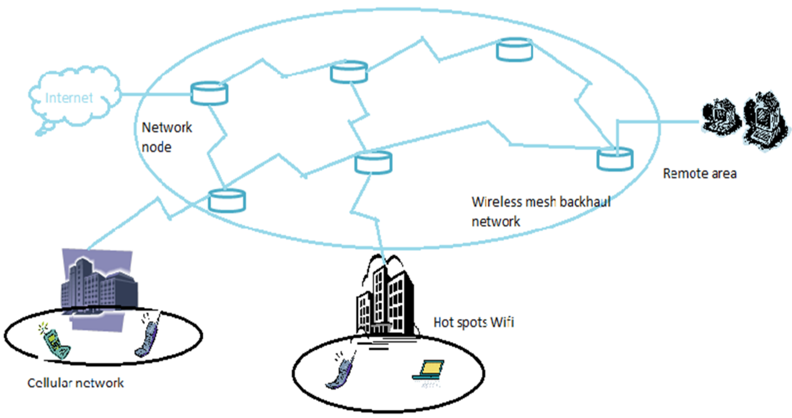

Fig. 1 Architecture of WiMAX

Beyond just providing a single last hop access to the Internet Service Provider (ISP), WiMAX technology can be used for creating wide-area wireless backhaul network. When a backhaul-based WiMAX is deployed in Mesh mode, it does not only increase the wireless coverage, but it also provides features such as lower backhaul deployment cost, rapid deployment, and re configurability. Various deployment scenarios include citywide wireless coverage, backhaul for connecting 3G RNC with base stations, and others [14]. WiMAX specifies the air interface, including the medium access control (MAC) and physical (PHY) layers, of BWA. The role of the PHY layer is reliable delivery of data from the transmitter to the receiver, using physical medium such as radio frequency, light waves or copper wires. Usually, the PHY layer has no knowledge about the QoS or the type of application such as VOIP, HTTP or FTP. MAC is responsible for controlling and multiplexing various links over the physical layer. These standards define two operational modes for communication namely:

A. Point-to-multipoint mode: It requires all the subscriber station to be within clear LOS transmission range of the base station (BS). In this mode, multiple subscriber stations are served by a centralized base station.

B. Mesh mode: the subscriber station communicate with each other within non-LOS transmission range of the SSs. The nodes are organised in an adhoc manner. Each station is able to communicate directly to a number of other stations in the system.

IEEE 802.16 MAC was designed for point-to-multipoint broadband wireless communication. The main function of the WiMAX MAC layer is to provide an interface between the higher transport layers and the physical layer. The MAC layer takes packets from the upper layers; these packets are called MAC Service Data Units (MSDUs) and organize them into MAC Protocol Data Units (MPDUs) for transmission over the air. For received transmissions, the MAC layer does the reverse. Each MAC PDU consists of a fixed-length MAC header, a variable-length payload, and an optional cyclic redundancy check (CRC). MAC PDU headers are of two types: generic MAC header and bandwidth request header.

1) *Generic MAC Header:* Format of GMH as specified in IEEE 802.16-2004(IEEE, 2004) is illustrated in below Fig. 2.

Generic MAC Header (6 bytes)	Payload (optional) (0 to 2014 bytes)	CRC (optional) (4 bytes)

Bits

1	1	6	1	1	2	1	11	16	8
HT	EC	Type	Rsv	CI	EKS	Rsv	LEN	CID	HCS

Fig. 2 Generic Header Format

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a) The Header Type (HT) consists of a single bit set to 0 for GMH.
b) The Encryption Control (EC) field specifies whether the payload is encrypted or not and is set to 0 when the payload is not encrypted and to 1 when it is encrypted.
c) The Type field indicates the subheaders and special payload types present in the message payload (five possible sub header types).
d) The Reserved (Rsv) field is of two bits and is set to 002.
e) The Extended Subheader Field (ESF) field consists of a single bit set to 1 if the extended subheader is present and follows the GMH immediately (applicable in both the downlink and uplink).
f) The CRC Indicator (CI) field is a single bit set to 1 if a CRC is included and is set to 0 if no CRC is included.
g) The Encryption Key Sequence (EKS) field is two bits. It is the index of the Traffic Encryption Key (TEK) and initialization vector used to encrypt the payload. Obviously, this field is only meaningful if the EC field is set to 1.
h) The Length (LEN) field is 11 bits long. It specifies the length in bytes of the MAC PDU including the MAC header and the CRC, if present.
i) The Connection Identifier (CID) field is 16 bits long and represents the connection identifier of the user.
j) The Header Check Sequence (HCS) field is 8 bits long and is used to detect errors in the header [5].

2) *Bandwidth Request Header:* Bandwidth request headers, shown in Fig. 3, have the same size as generic MAC frame headers, but their content differs. A bandwidth request PDU consists only of a header and does not contain any payload. The fields of the header are provided below.

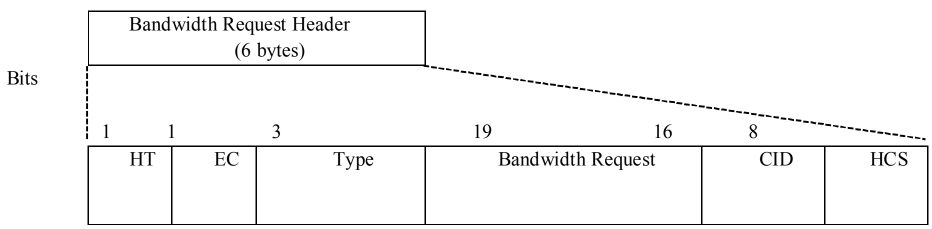

Fig. 3 Bandwidth Request Header

a) The Header Type HT field is a single bit set to 1 for BRHs.
b) The EC is a single bit set to 0, indicating no encryption.
c) The Type field is 3 bits long and indicates the type of BRH. It can take two values, namely 000 for incremental and 001 for aggregate bandwidth request.
d) The bandwidth request (BR) field is 19 bits long and indicates the number of bytes requested.
e) The CID field is 16 bits long and represents the CID of the connection for which uplink bandwidth is requested.
f) The HCS field is 8 bits long and is used to detect errors in the header.

Interference: WiMAX/802.16 mesh network is an emerging infrastructure that offers a cost-effective deployment for high speed wireless broadband access to the backhaul network. However, as in most wireless multi-hop networks, WiMAX/802.16 mesh suffers from interference that decreases considerably the throughput and increase the delay which causes spatial reuse of the network. Although single hop WiMAX provides high flexibility to attain Quality of Service in terms of data throughput, achieving the same in multi-hop WiMAX mesh is challenging. One of the major problem is dealing with the interference from transmission of the neighbouring WiMAX nodes. Interference can be the result of coexistence with the other technologies. In Europe, FCC in 2002 approved an unlicensed frequency band from 3.1 to 10.6 GHz with maximum transmission power of -41.3 dBm/MHz for short range, high and low data rate applications on notebook PCs, headset and consumer electronics for Ultra Wide Band (UWB) and for WiMAX, the band 3.3 GHz and 3.5GHz are reserved for fixed and mobile version. Consequently, the interference from UWB radio can cause the Noise Floor (NF) by an amount sufficient to cause performance degradation at the WiMAX subscriber receiver [15].

In this paper, we propose a mathematical model that minimizes interference, in WiMax/802.16 mesh networks, where the effect of the interference from neighboring transmissions and hidden terminals are incorporated. In this Interference-Hidden aware (IH-aware) model, the BS centrally performs time slot allocation for *SS*s (according to their bandwidth demands) taking into account the interferences each *SS* yields on its neighboring *SS*s, as well as avoiding the collisions that may arise from hidden terminals (*SS*s outside the transmission range of each other send data to a common *SS* neighbor at the same time). Hence, the proposed model developed finds the best network configuration (optimal routing paths and associated time slots) that minimizes interference. Furthermore we consider the multi-path property in developing our model, where several potential routes exist

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between a *SS* and the BS [6].

There are several scheduling algorithm for WiMAX some of them and their impacts are illustrated here: In the TREE scheduling, the duplexing status of nodes depends on tree level such that nodes at even and odd tree levels have opposite duplexing mode, i.e., transmitting or receiving. The duplexing status of one node alternates slot by slot. In this way, the TREE scheduling is partially opportunistic and able to determine the duplexing status for nodes as required by TDD operations. The main shortcoming of the TREE scheduling is that the tree-mapping only considers part of the available radio links to be scheduling candidates. [4]

The other or proposed scheduling algorithm is the hexagonal scheduling algorithm which is fully distributed, capable of selecting high-utility link combinations to achieve multi-user diversity gain, and generating reasonably temporal-correlated interference needed to ensure satisfactory scheduling and power control performance [4]. Specifically, we have introduced a link utility definition as the scheduling metric so that throughput demand specified by the routing algorithm in use can be passed onto the scheduler to enforce. The obtained results are quiet optimist and realistic which gives a vital impact on the network simulation.

II. LITERATURE SURVEY

Yun Hou et.al (2009) proposed a framework for multiuser diversity gain and quality-of-service (QoS) in wireless mesh networks in which they mainly focused over the computational complexity of finding optimal link schedule for the wireless mesh network with time division duplexing (TDD) operation. Moreover, they proposed a heuristic distributed algorithm and a link utility function for wireless mesh networks. The proposed performance analysis showed the long term throughput allocation coverage to the desired level which was proportional to the requirement specified by the ranking protocol in use to guarantee QoS and maintain strong temporal co-relation of interference which was required to ensure proper channel prediction for distributed scheduling and power control. At last but not least, the author compared the proposed scheduling algorithm with a previously proposed tree scheduling and centralized "ideal" scheduling. Finally they concluded that the proposed heuristic scheduling algorithm was fully distributed and compare of selecting high utility link combination to achieve multiuser diversity gain.

Hung-Yu Wei (2005) et.al proposed a scheme for interference aware cross-layer design for WiMAX mesh networks. They mainly dealt with the efficient approach for increasing the utilization of WiMAX mesh network through appropriate design of multi hop routing and scheduling. In this paper, the author proposed a scheme which includes a novel interference-aware route construction algorithm and an enhanced centralized mesh scheduling scheme that consider both traffic load demand and interference condition. Finally, they concluded that the simulation result of the proposed scheme effectively improved the network throughput performance in IEEE802.16 mesh networks and achieved high spectral utilization.

Gurpal Singh Sidhu et.al (2012) worked over performance evaluation of WiMAX networks. In this paper, the author analysed and simulated the different modulation schemes for WiMAX. They worked over different WiMAX networks such as IEEE 802.16e-2005, 802.16g, 802.16k, 802.16h,802.16i and 802.16j.In this paper, the author mentioned that WiMAX throughput mainly depends on the factors like channel spacing number of sub carriers inside a channel, sub-carriers used as pilot carriers, sub-carriers used as guard carriers, symbol duration, modulation rates and effective code rates. Moreover, they investigated the behaviour of adaptive modulation on technique of WiMAX network in which the adaptive modulation used quadrates phase shift keying , 16-quadrates amplitude modulation for modulating the signal and finally concluded that the QPSK was a little bit more reliable than other like 16-QAM.

D.chieng et.al (2011) worked over scalability analysis of multi-tier hybrid WiMAX-Wi-Fi multihop network .In this paper, the author attempted to provide same insight on how different possible hybrid topology design perform in terms of required node density. This performance metric was particularly important as it had a direct implication on the number of cell sites required and deployment cost moreover, the author looked at blanket -like deployment with hexagonal cell layout adapted in typical cellular network. Furthermore, the author provided a high level analysis on the performance of different possible WiMAX-Wi-Fi multi-tier in terms of BS or MRAR density and concluded that the performance of WiMAX-Wi-Fi multi-tier network was design particularly the number of hops within the Wi-Fi cluster.

III. AD HOC ON-DEMAND DISTANCE VECTOR (AODV) ROUTING PROTOCOL

A routing protocol determines how nodes interact with each other to route packets between various nodes in an ad hoc network. An ad hoc network (E. Royer *et al* 1999) is a network of mobile nodes which does not have a pre-existing infrastructure. They are self-organised and connected by wireless links. Each node is free to move independently and participate in routing by forwarding data to other nodes.

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The Ad hoc On-Demand Distance Vector (AODV) algorithm enables dynamic, self-starting, multihop routing between participating mobile nodes wishing to establish and maintain an ad hoc network. AODV is an on demand algorithm, meaning that it allows mobile nodes to obtain routes quickly for new destinations, and does not require nodes to maintain routes to destinations that are not in active communication. AODV allows mobile nodes to respond to link breakages and changes in network topology in a timely manner. AODVs most important distinguishing feature is its use of sequence numbers for every route entry to ensure the freshness of routes. The operation of AODV is loop-free, self-starting, and scales to large numbers of mobile nodes. When links break, AODV causes the affected set of nodes to be notified so that they are able to invalidate the routes using the lost link [7].

A. Route Discovery

Route discovery process starts when a source node wants to send a packet to a new destination node for which it has no routing information in its table. The source node initiates route discovery process using Route Request (RREQ) and Route Reply (RREP) messages. It broadcasts RREQ to its neighbours. The RREQ packet contains the following fields:

1) Source Address
2) Source Sequence Number
3) Broadcast ID
4) Destination Address
5) Destination Sequence Number
6) Hop Count

The combination of source address and broadcast ID uniquely identifies each RREQ. Broadcast ID is incremented each time the source node initiates RREQ. Each neighbour either satisfies the RREQ by sending a route reply (RREP) back to the source or re-broadcasts the RREQ to its own neighbours after increasing the hop count. Notice that a node may receive multiple copies of the same route broadcast packet from various neighbours. When an intermediate node receives a RREQ, which it has already received with the same broadcast ID and source address, it drops the redundant RREQ and does not rebroadcast it.

Source Address	Source ID	Source Sequence Number	Destination Address	Destination Sequence Number	Hop Count

Fig. 4 RREQ Parameters

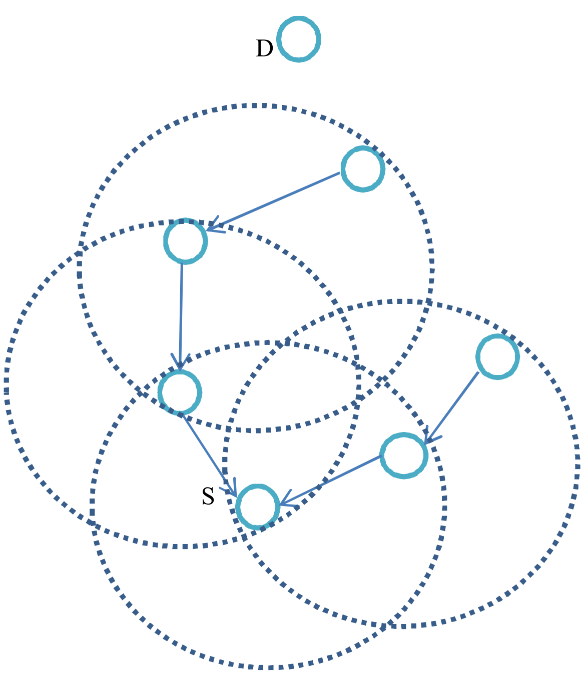

Fig. 5a Reverse Path Formation

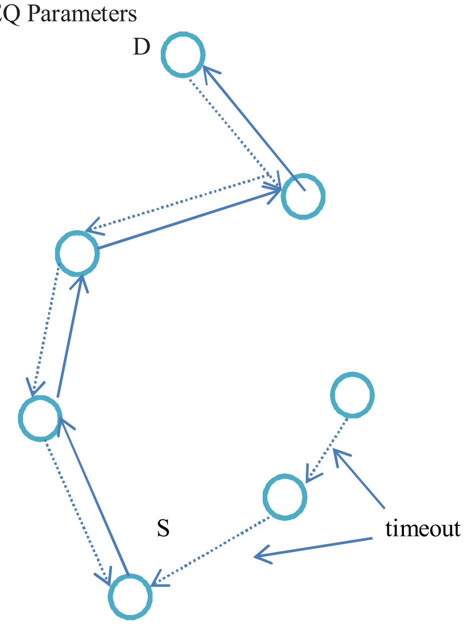

Fig. 5b Forward Path Formation

A. Reverse Path Setup

RREQ packet contains two sequence numbers: the source sequence number and the last destination sequence number known to the source. The source sequence number is used to maintain freshness information about the reverse route to the source and the destination sequence number specifies how fresh a route to the destination must be before it can be accepted by the source [12]. As the RREQ travels from a source to various destinations it automatically sets up the reverse path from all nodes back to the source, as shown in Fig. 5a To set up a reverse path, a node records the address of the neighbor from which it received the first copy of the RREQ. These reverse path route entries are maintained for at least enough time for the RREQ to traverse the network and produce a reply to the sender.

B. Forward Path Setup

Eventually, a RREQ will reach an intermediate node (that possesses a current route to the destination) or the destination itself. The receiving node first checks that the RREQ was received over a bi-directional link. The node compares the destination sequence number in the RREQ with the destination sequence number stored in its own route entry and replies when it has a route with a sequence number that is greater than or equal to that contained in the RREQ. The node unicasts a Route Reply (RREP) back to its neighbor from which it received the RREQ, as shown in Fig. 5b. A RREP packet contains the following fields:

1) Source Address
2) Destination Address
3) Destination Sequence Number
4) Hop Count
5) Lifetime

Source Address	Destination Address	Destination Seq. No.	Hop Count	Life Time

Fig. 6 RREP Parameters

When the RREP is routed back to the source node along the reverse path and received by an intermediate node, it sets up a forward pointer to the node from which the RREQ came, updates its timeout information for route entries to the source and destination, and records the latest destination sequence number for the requested destination**. [4 aodv]** The source node can begin data transmission as soon as the RREP received as the route between the source and the destination has been established.

C. Route Maintenance

A route discovered between a source node and destination node is maintained as long as needed by the source node. Since there is movement of nodes in mobile ad hoc network and if the source node moves during an active session, it can reinitiate route discovery mechanism to establish a new route to destination whereas if the destination node or some intermediate node moves, the node upstream of the break initiates Route Error (RERR) message to the affected active upstream neighbors/nodes [13]. Consequently, these nodes propagate the RERR to their predecessor nodes. This process continues until the source node is reached. When RERR is received by the source node, it can either stop sending the data or reinitiate the route discovery mechanism by sending a new RREQ message if the route is still required.

IV. SIMULATION AND PERFORMANCE ANALYSIS

We use NS-2 simulation to carry out simulation. NS-2 is an event-driven tool useful in studying the dynamic nature of computer network. It provides the simulation of wired as well as wireless network functions and protocols (e.g., routing algorithms, TCP, UDP). In general, NS2 provides users with a way of specifying such network protocols and simulating their corresponding behaviours. A hybrid network consisting of IEEE 802.11/WLANs and IEEE 802.16/WiMAX is a strong contender since both technologies are designed to provide ubiquitous low cost, high speed data rates, QoS provisioning, and broadband wireless internet access The performance of the integrated WiMAX- Wi-Fi network is calculated when interference (such as noise) occurs in the network and compared when there is no interference in the network.

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TABLE I

SIMULATION PARAMETERS

Parameter	Values
Simulator Name	NS-2 simulator
Standards	802.16a, 802.11b
No. Of nodes	27
Traffic type	FTP (TCP)
Routing protocol	AODV
Channel Type	Wireless Channel
Mobility Model	Two Ray Ground Propagation Model
Network Interface Type	Wireless Phy IEEE 802.16

Network delay is an important design and performance characteristic of a computer network or telecommunications network. The delay of a network specifies how long it takes for a bit of data to travel across the network from one node or endpoint to another. It is typically measured in multiples or fractions of seconds. Delay may differ slightly, depending on the location of the specific pair of communicating nodes [8]. There is a certain minimum level of delay that will be experienced due to the time it takes to transmit a packet, so this adds up more variable level of delay due to network congestion.

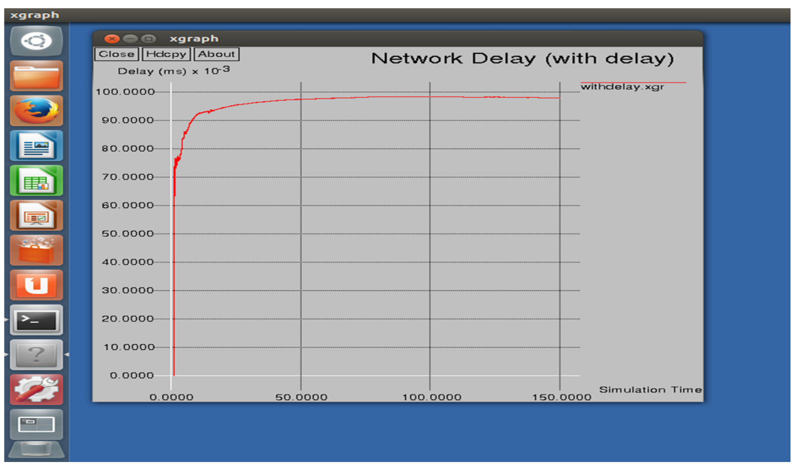

Fig. 7 Screenshot of proposed result with delay

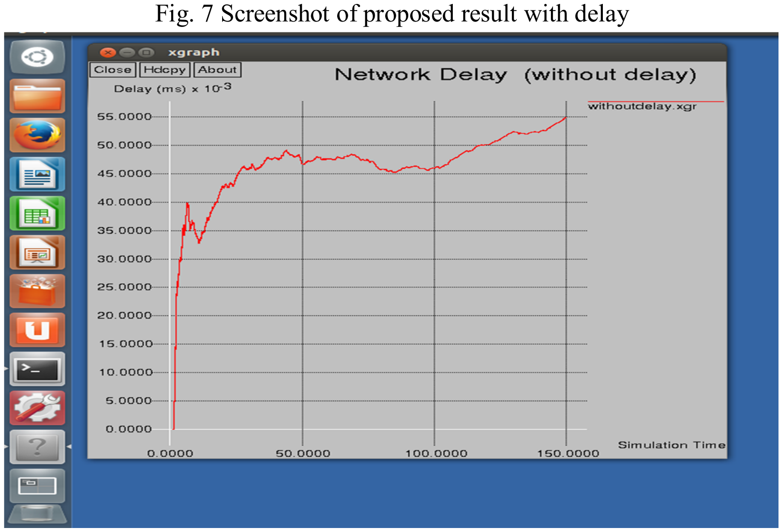

Fig. 8 Screenshot of proposed result without delay

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V. CONCLUSION

This paper has presented a description on the wireless technologies and discusses the two popular wireless technologies namely: Wi-Fi and WiMAX technologies. The factors that cause interference and what are various effects of the interference on these technologies are also discussed. The reactive protocol AoDV is also discussed in great detail. With the help of the NS-2 simulator throughput of the integrated Wi-Fi/WiMAX is calculated. This work shows that throughput of the integrated Wi-Fi/WiMAX network increases with time when there is no interference whereas the throughput of the integrated Wi-Fi/WiMAX network becomes stable after a certain point of time. Therefore, interference decreases the network throughput and makes the network weak and unreliable.

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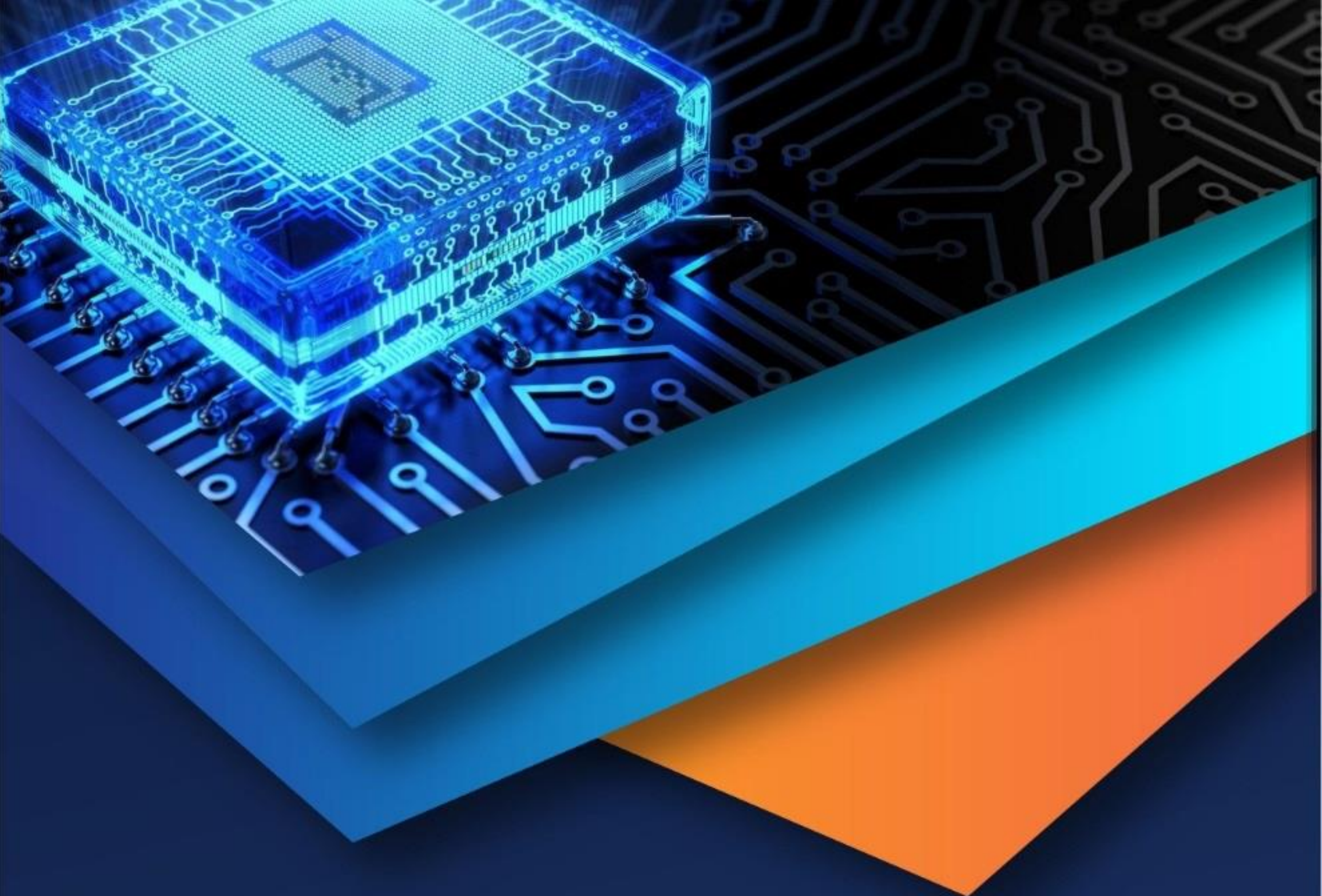

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